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Density and Bending Strength Characteristics of North Western Nigerian Grown Eucalyptus Camaldulensis in Relation to Utilization as Timber

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ABSTRACT

The density and bending strength of *Eucalyptus camaldulensis* Denhn (river red gum) grown in the North-western Nigeria were investigated. The tests were conducted using standard methods of testing clear wood specimens. ANOVA was used to analyze the data while Duncan's New Multiple range Test (DNMRT) was used to separate the mean. The study revealed that, *E. camaldulensis* has an average density of 977.58 kg m^{-3}. Similarly, *E. camaldulensis* had static bending strength of 133.33 N mm^{-2}. *E. camaldulensis* collected from three geographical locations were significantly different for both the density and bending strength. The modulus of elasticity (stiffness) was 15219.89 N mm^{-2}. Comparison between the density and bending strength of *E. camaldulensis* with other wood species commonly utilized as timber in Nigeria revealed that the wood was suitable for timber production.

Key words: Density, bending strength, modulus of elasticity, timber, *Eucalyptus camaldulensis*

INTRODUCTION

The rate of wood consumption for construction and for furniture in northern Nigeria is growing by the day. This part of the country relies heavily on wood supplies from the south. Consequently, with population growth and the corresponding upsurge in demand for wood and wood based products, there has been rapid growth in the rate of wood consumption in the country. Wood supply is now dwindling and its price becoming more and more expensive. The known species are getting depleted. Above all, the rates of growth of the indigenous savanna tree species are generally low and hence cannot meet the ever increasing demand of the people for wood and wood products (Otegbeye, 2004). As such, substantial areas of erstwhile very low productive forests have since been converted into productive plantations of fast growing exotics such as *Pinus* spp., *Eucalyptus* spp., *Tectona grandis, Gmelina arborea, Acacia* spp., *Azadirachta indica* etc, by the various state forestry establishments across the savanna zones (Momodu *et al.*, 1997). Declining availability of the prime economic species in timber market has led to the investigation of lesser-used species (Oluwafemi and Adegbenga, 2007; Kayode, 2007). Oluwafemi and Tunde (2008) conducted a study on the quality of *Sterculia setigera* wood species though for a different utilization end product (pulp and paper production). This dictates the need to explore wood species other than the native ones with a view to finding an alternative supply. The density is the most used criterion for classification in the area of strength while the bending strength is relevant in the domain of structural utilization (Lucas and Olufemi, 2001). It is against this backdrop that this research intends to explore the utilization potentials of *E. camaldulensis* (Dehnh)-an indigenized exotic species whose drought tolerance and adaptability have made it particularly suitable for the semi-arid regions.

Eucalyptus species are native to Australia but grown extensively worldwide as short rotation hardwoods for a variety of products and as ornamentals. They have been successful as exotics because of their capacity for fast growth and tolerance of harsh environments involving many effective adaptations: indeterminate growth, coppicing, lignotubers, drought, fire, insect resistance and tolerance of soil acidity and low fertility (Rockwood *et al.*, 2008). *Eucalyptus* species are the most valuable and widely planted hardwood in the world (18 million ha in 90 countries (FAO, 2005). Eucalypts are grown extensively as exotic plantation species in tropical and subtropical regions throughout Africa, South America, Asia and Australia and, in more temperate regions of Europe, South America, North America and Australia. In the regions of faster growth, rotations were as short as 5 years with yields as high as 70 m^3/ha/yr. Four species and their hybrids from this subgenus, *Eucalyptus grandis* (EG), *E. urophylla* (EU), *E. camaldulensis* and *E. globulus*, account for about 80% of the eucalypt plantations worldwide (Rockwood *et al.*, 2008).

Approximately four decades ago, the growing of *Eucalyptus* under community forestry was to meet timber supply due to rise in demand; however, this orientation has changed because of its emerging economic benefit to the land users (Meknonnen, 2000, Liu and Li, 2010). Kebebew (2010) reported that growing of Eucalyptus increased the annual income of rural farmers. In addition, Eucalypts are utilized worldwide for a wide array of products including pulp for high quality paper, lumber, plywood, veneer, solid and engineered flooring, fiberboard, wood cement composites, mine props, poles, firewood, charcoal, essential oils, honey, tannin and landscape mulch as well as for shade, windbreaks and phytoremediation (Tournier *et al.*, 2003; Gorrini, *et al.*, 2004; Krzysik *et al.*, 2001; Foley and Lassak, 2004; Coutts, 2005; Ogunwande *et al.*, 2005; Barton, 2007).

The success of this study is likely going to mitigate a number of problems that are encountered in the movement of saw timber from the south to the north. Among these are high cost of fuel, poor road network, labor cost, all in addition to the problems of vehicle purchase and maintenance which raise the cost of timber used for construction, furniture and other wood-based products in the northern part of the country (Akpan, 2006). The price of wood has always risen above the man can afford.

Based on the aforementioned, it is thought here that if alternative wood species that are locally available are tapped, they could supplement or even substitute the over depleted rain forest species available from the south. That could solve some of the problems hitherto experienced. *E. camaldulensis* which has been found to be highly adaptable to this region, is widely grown as wind break to protect the any region from desert encroachment (Jackson and Ojo, 1973; Sharma *et al.*, 2005) has been chosen for this study. The timber potential of *E. camaldulensis* is encouraged from result of trials from other places (Sharma *et al.*, 2005). Therefore, the density and bending strength of *E. camaldulensis* grown in the North-western Nigeria were investigated to confirm the possibility of its use in the timber industry.

MATERIALS AND METHODS

Study area: The study was conducted in three locations in the former Sokoto state, now Sokoto, Kebbi and Zamfara states. The three locations/study sites are Gidan Kaura town (Gada Local

Government area, Sokoto state) Kalgo town, (Birnin Kebbi Local Government area, Kebbi state) and Kaura Namoda town (Kaura Namoda Local Government area, Zamfara state). They are located in the north western part of Nigeria between latitude 10° 8 and 13° 55' N and longitudes 3° 30' and 7° 15' E with a total land area of approximately 94,588 km^2 (Ojanuga, 2006).

Procedure for tree sampling: In each of the sites selected for the study, matured *E. camaldulensis* trees were chosen by purposive selection using a diameter of at least 20 cm to be considered as small diameter log as a basis for selection in the three study areas for the research. Adekunle (2007) only used tree with diameter at breast height of = 20 cm for timber volume estimation. A total of 5 tree samples were selected from each of the three research locations as in Mackes *et al*. (2005).

For density determination, specimens were cut to standard sizes in accordance with STAS 6087:72 as cited by Pescarus and Cismaru (1979).

$$\text{Density} = \frac{\text{Mass of oven dry wood sample}}{\text{Volume of oven dry wood sample}} \; (\text{kg m}^{-3})$$

The bending strength test was carried out after almost four months of keeping the samples in the open laboratory space and confirming the moisture content at 12%. The test was done using the procedure prescribed by ASTM (2006).

Statistical analysis: The data collected for all test parameters were analyzed using analysis of variance (ANOVA) at $p<0.05$ probability level and Duncan's New Multiple range Test (DNMRT) was used as a follow up analysis to separate the means.

RESULTS

Wood density: Values of density for all the 225 specimens were computed based on masses as shown in Table 1. At 12% moisture content, results showed that density variation ranged from 920.30 kg m^{-3} to 1084.25 kg m^{-3} with a mean value of 1003.58 kg m^{-3} in Sokoto. In Kebbi, the density variation was from 920.89 kg m^{-3} to 1082.07 kg m^{-3} with a mean value of 1008.77 kg m^{-3} while in Zamfara state, the density variation showed lower values ranging from 857.48 kg m^{-3} to 964.74 kg m^{-3}, with a mean value of 920.39 kg m^{-3}. The overall mean density value for *E. camaldulensis* across the three study sites was 977.58 kg m^{-3}. Table 1 shows the density values of *E. camaldulensis*.

Table 1: Density (kg m^{-3}) of *E. camaldulensis* (Denhn) from Sokoto, Kebbi and Zamfara states of north western Nigeria

Tree sample	Sokoto				Kebbi				Zamfara				Overall mean
	*1	*2	*3	Mean	*1	*2	*3	Mean	*1	*2	*3	Mean	
1	974.22	953.78	920.30	949.43[d]	945.19	961.78	984.30	963.76[e]	896.30	886.81	907.85	896.99[d]	936.73
2	1054.82	1039.11	1033.78	1042.57[a]	1058.37	1007.41	1082.07	1049.35[a]	949.63	937.48	964.74	950.62[a]	1014.16
3	964.74	1005.04	978.37	982.72[c]	920.89	1018.37	1043.85	994.37[d]	960.30	935.11	938.07	944.49[b]	973.86
4	1084.15	1039.41	1015.11	1046.22[a]	1054.22	947.85	1031.11	1011.06[c]	863.11	920	857.48	880.20[e]	979.16
5	999.11	970.37	1021.33	996.94[b]	1048.89	1036.74	990.52	1025.25[b]	954.96	909.63	914.37	926.32[c]	983.99
Mean	1015.41	1001.54	993.78	1003.58[a]	1005.51[a]	994.43	1026.37	1008.77[a]	926.86	917.81	916.50	920.39	977.58[b]
SD	46.49	35.96	41.11	36.74	59.75	33.96	36.02	28.83	40.22	18.54	35.65	27.36	24.76

*1: Bottom, *2: Middle, *3: Top, Values in column with same latter are not significantly different

Table 2: Static bending strength parallel to grain (N mm^{-3})

Tree sample	Sokoto *1	*2	*3	Mean	Kebbi *1	*2	*3	Mean	Zamfara *1	*2	*3	Mean	Overall mean
1	140.46	88.86	147.15	125.49^{c}	153.84	98.42	124.22	125.49^{c}	135.68	140.46	152.88	143.01^{a}	131.33
2	114.64	150.97	149.06	138.23^{a}	103.19	157.66	138.55	133.13^{b}	129.95	151.92	116.57	132.81^{c}	134.73
3	93.64	157.66	142.37	131.22^{b}	153.84	145.24	126.13	141.74^{a}	141.41	154.79	105.11	133.77^{c}	135.58
4	92.68	138.55	150.01	127.08^{c}	124.22	107.97	152.88	128.36^{c}	137.59	151.92	148.10	145.87^{a}	133.77
5	113.70	115.62	153.84	127.72^{c}	142.37	123.26	157.66	141.10^{a}	126.13	119.44	147.15	130.91^{c}	131.30
Means	111.03	130.33	148.49	129.95^{b}	135.49	126.51	139.89	133.96^{ab}	134.15	143.71	133.96	137.27^{a}	133.33
SD	17.47	25.21	3.76	17.30	19.45	22.20	13.57	6.56	5.46	13.09	19.32	5.99	1.75

*1: Bottom, *2: Middle, *3: Top, Values in column with same latter are not significantly different

Table 3: Modulus of elasticity (MOE) in bending (N mm^{-2})

Tree sample	Sokoto *1	*2	*3	Mean	Kebbi *1	*2	*3	Mean	Zamfara *1	*2	*3	Mean	Overall mean
1	16070.17	9048.49	16891.23	14003.3^{e}	18886.38	10568.52	13713.21	4389.37^{d}	15075.19	16340.16	18650.03	16688.46^{b}	15027.04
2	12428.49	17410.78	17795.02	15878.10^{a}	11341.88	15987.93	15925.2	14418.34^{c}	15006.49	19259.6	12487.07	15584.39^{d}	15293.61
3	9608.44	18341.0	16451.91	14800.45^{b}	18403.45	16716.21	13809.69	16309.78^{a}	16462.38	19388.71	11203.37	15684.89^{cd}	15598.35
4	9454.35	15737.11	17859.82	14350.43^{cd}	14508.4	12594.66	17797.17	14966.74^{b}	15669.71	18320.4	17547.83	17245.98^{a}	15521.05
5	12164.95	12331.3	18428.92	14308.39^{d}	16397.18	13590.39	18912.96	16300.18^{a}	14478.2	12849.79	17280.85	14869.61^{e}	15159.39
Means	11945.28	14573.74	17483.38	14668.13^{c}	15907.46	13891.54	16031..65	15276.99^{b}	15338.39	17271.13	15433.83	16014.65^{a}	15319.89
SD	2406.74	3439.52	713.78	656.34	2762.09	2244.49	2085.31	864.29	677.12	2447.35	2993.48	845.60	214.58

*1: Bottom, *2: Middle, *3: Top, , Values in column with saine latter are not significantly different

Static bending: Static bending of *E. camaldulensis* was 133.33 N mm^{-2} (Table 2). In Sokoto, values for static bending ranged from 88.86 to 153.84 N mm^{-2} with a mean of 125.29 N mm^{-2}. Static bending for Kebbi and Zamfara states ranged from 98.42 to 157.66 N mm^{-2} and 105.11 2 to 154.79 N mm^{-2} with mean values of 133.96 and 137.27 N mm^{-2}, respectively. From the ANOVA, it is depicted that the locations show significant difference ($p<0.05$) while all other parameters were highly significant ($p<0.01$) in static bending stress.

Modulus of elasticity (MOE): In Sokoto, the modulus of elasticity in bending ranged from 9048.49 to 18428.92 N mm^{-2}, with a mean of 14668.13 N mm^{-2} (Table 3). Values for Kebbi and Zamfara states ranged from 10568.52 to 18912.96 N mm^{-2} and 11203.37 to 19388.71 N mm^{-2}, respectively. Mean values for the two states were 15276.99 and 16014.65 N mm^{-2} respectively. The overall mean value across the northwest ecological zone was 15319.89 N mm^{-2} (Table 3).

DISCUSSION

The density values of *E. camaldulensis* as revealed in this study favorably compares with timber specification as stipulated in the standards of NCP 2 (1973). With the high density of *E. camaldulensis* the wood would be especially attractive for general timber utilization in the north zone in particular and in the country in general. By these values, the wood is at a greater advantage over the light density species. Similarly, the wood stands another advantage of repelling insects and fungi attack for which light wood species are more susceptible (Raven *et al.*, 1997). The value tends towards the high density category in which case the use may be restricted to structural construction. When compared with the available wood species. *E. camaldulensis* will thus, be a very promising timber species. Some of these local timber species and their densities include *Triplochiton scleroxylon* (400 kg m^{-3}), *Pycanthus angolensis* (480 kg m^{-3}), *Khaya ivorensis* (485 kg m^{-3}), *Gosweilerodendron balsamiferum* (497 kg m^{-3}), *Terminalia ivorensis* (550 kg m^{-3}), *Mitragyna ciliata* (560 kg m^{-3}) and *Terminalia superba* (580 kg m^{-3}) (Hall, 1998; Kwame, 2001). Others are *Mansonia altissima* (615 kg m^{-3}), *Entandrophragma cylindricum* (620 kg m^{-3}) and *Nauclea diderrichii* (660 kg m^{-3}) (Scheffer and Morrell, 1998; Ogunsanwo and Onilude, 2002; Fuwape and Fabiyi, 2003). However, the density of *E. camaldulensis* was lower than that of *Gliricidia sepium* whic was 1025 kg m^{-3} (Oluwafemi and Adegbenga, 2007). The fact that the density of *E. camaldulensis* was higher than most commercial timber indicates that it is a heavy wood but not as heavy as *G. sepium*. Poku *et al.* (2001) stated that wood density is a good indicator for selection of wood for use. It therefore implies that *E. camaldulensis* could be used where most of the commercially available Nigerian timbers are being utilized like in building and construction applications. The Analysis of Variance (ANOVA) shows that there was highly significant difference between locations and trees as well as between location/tree and tree region interaction. However, no significant difference was observed between regions. The significant difference in the location may be due to the site quality.

Results for static bending showed that *E. camaldulensis* with mean value of 133.33 N mm^{-2} has a very high static bending stress. This places the wood at an advantage as it compares favorably with some commercially important wood species in Nigeria. For instance, Abura (*Mitragyna ciliata*) = 79 N mm^{-2}, Afara (*Terminalia superba*) = 106 N mm^{-2}, Afromosia (*Pericopsis elata*) = 128 N mm^{-2}, Ebony (*Diospyros \crassiflora*) = 190 N mm^{-2}, Ekki (*Lophira alata*) = 207 N mm^{-2}, Iroko (*Chlorophora exelsa*) = 130 N mm^{-2}, Mahogany (*Khaya ivorensis*) = 110 N mm^{-2}, Obeche (*Triplochiton scleroxylon*, from natural forest) = 77 N mm^{-2} and Teak (*Tectona grandis*) = 107 N mm^{-2}) and *Nauclea diderrichii* (209 N mm^{-2}) (Fuwape and Fabiyi, 2003). Static bending strength of *E. camaldulensis* is higher than those of *G. sepium* = 120 N mm^{-2} and plantation grown *T. scleroxylon* = 62 N mm^{-2} (Ogunsanwo and Onilude, 2002; Oluwafemi and Adegbenga, 2007). However, it has similar bending strength with that of teak = 136 N mm^{-2} (from a slow growing provenance in India) reported by Bhat and Priya (2004). The significant difference in the location may be due to the site quality.

From the findings, it is clear that *E. camaldulensis* with a modulus of elasticity value of 15319.39 N mm^{-2} falls within the range of other eucalyptus species as well as with some timber species commonly used for structural purposes in Nigeria. Some of the eucalyptus species and their MOE values include *E. paniculata* (12100 N mm^{-2}), *E. pilularis* (16800 N mm^{-2}), *E. diversicolor* (17900 N mm^{-2}), *E. cloeziana* (19521 N mm^{-2}), *E. microcorys* (20500 N mm^{-2}), *E. grandis* and *E. terreticornis* (20869 N mm^{-2}) and *E. paniculata* (22700 N mm^{-2}).

E. camaldulensis satisfies the requirements of NCP 2 (1973) in respect of the standard's stipulation for timbers for structural applications in the country. Values of modulus of elasticity of some of the commonly used timbers in Nigeria include *Ceiba pentandra* (4280 N mm^{-2}), *Triplochiton scleroxylon* (5500 N mm^{-2}), *Antiaris africana* (5800 N mm^{-2}), *Alstonia boonei* (6700 N mm^{-2}), *Gossweiloredendron balsamiferum* (7600 N mm^{-2}), *Daniellia klainei* (8100 N mm^{-2}), *Pycanthus angolensis* (8445 N mm^{-2}), *Khaya ivorensis* (10000 N mm^{-2}), *Eribroma oblonga* (10070 N mm^{-2}), *Chlorophora exelsa* (11000 N mm^{-2}) and *Mansonia altissima* (11175 N mm^{-2}) ALS (2000). The modulus of elasticity of *E. camaldulensis* is higher than 6239 N mm^{-2} obtained for plantation grown *T. scleroxylon* (Ogunsanwo and Onilude, 2002). Since most Nigerian timbers are fast declining in the timber market due to over-exploitation to meet exportation demand, there is the need to find good source of substitute for them (Ogunsanwo, 2000; Oluwafemi and Adegbenga, 2007). Therefore, with the density and mechanical properties of *E. camaldulensis* obtained in this study, its wood could be used various applications like building, construction, flooring, cabinetry, furniture and other uses where high mechanical properties are required. Results show that there is no correlation between modulus of elasticity and density as increase in MOE does not translate to increase in density and this is different to findings by Desch (1992). The ANOVA revealed highly significant difference ($p<0.05$) among trees, locations regions as well as all levels of interactions. The follow up analysis further confirms this by showing significant differences between the means of Sokoto, Kebbi and Zamfara states as well as the regions. The significant difference in the location may be due to the site quality.

CONCLUSION

The large density values recorded places the wood at an elevated position of suitability in this respect enabling the wood to compete favorably with some commercially available timber species in Nigeria. The bending strength and modulus of elasticity values compare favorably and even superior to some of the species presently used in Nigeria. It can be concluded from the present study that *E. camaldulensis* is a promising species for timber industry in the north western part of Nigeria and in the nation in general.

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